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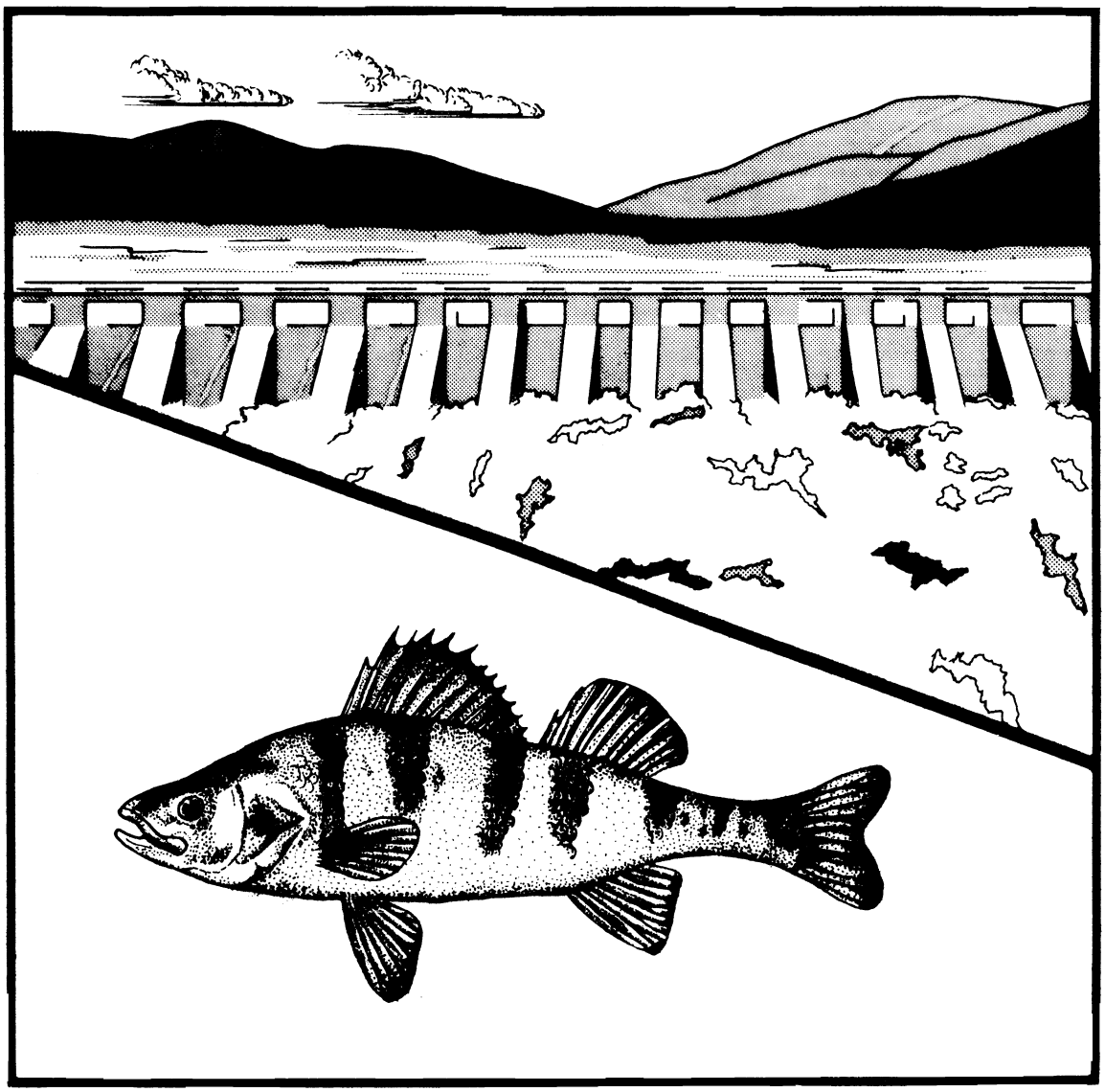

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HABITAT SUITABILITY INDEX MODELS: A LOW EFFORT SYSTEM FOR PLANNED COOLWATER AND COLDWATER RESERVOIRS

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PREFACE

The system presented in this publication is designed to classify proposed coolwater and coldwater reservoirs into four categories of fish habitat suitability based on the physical configuration of the reservoir basin, site climate, operational regime, and inflow characteristics. Instructions for deriving the reservoir classifications and sources of input data for the system are provided. Instructions are also provided for converting the system output into Habitat Suitability Indices (HSI's) for use with the U.S. Fish and Wildlife Service's Habitat Evaluation Procedures (HEP) (U.S. Fish and Wildlife Service 1980).[1] Data requirements for the system are low. The intended use of the system is for early planning stages of reservoir construction projects, when several alternatives must be evaluated.

[1]U.S. Fish and Wildlife Service. 1980. Habitat Evaluation Procedures (HEP) U.S.D.I., Fish and Wildlife Service, Division of Ecological Services, Washington, D.C. 102ESM. n.p.

SUMMARY

A novel approach to reservoir habitat evaluation is described and habitat ratings are proposed for five fish species in coolwater and coldwater reservoirs. This approach has the advantages of procedural simplicity and ready availability of input data; consequently, it has great potential utility as a screening tool in the early stages of the reservoir planning process.

Habitat suitability is determined on the basis of a composite score for five "primary" reservoir attributes (temperature, turbidity, nonliving cover, drawdown, and shallow cove frequency). The value of each primary reservoir attribute is determined from one or more "secondary" attributes, which are easily measured variables. Secondary attributes (for example, length of growing season or mean July air temperature) can be directly obtained, prior to construction, from published documents, maps, reservoir plans, and on-site inspections of the proposed reservoir basin.

Evaluation criteria and ratings are presented for rainbow trout (Salmo gairdneri), white sucker (Catostomus commersonii), yellow perch (Perca flavescens), common carp (Cyprinus carpis), and black crappie (Pomoxis nigromaculatus). These ratings were derived from literature reviews and from personal experience and knowledge of the authors; however, the system is easily adaptable to change upon further review, differences of opinion by experts, or evaluation of test results under diverse conditions.

This technique can be used to evaluate the suitability of a proposed reservoir for different species and to compare the outcomes of alternative construction plans. It could also be expanded to include additional species, which will improve its utility. The system should be useful in determining losses relative to benefits, trade-offs, and potential mitigation measures in reservoir projects.

CONTENTS

FIGURE

TABLES

ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

a	acres
A	surface area
D_L	shoreline development factor (or SDF)
ha	hectares
km	kilometers
L	shoreline length
m	meters
mg/l	milligrams per liter
TDS	total dissolved solids

SYMBOLS

K^+	potassium
Na^+	sodium
Ca^{++}	calcium
Mg^{++}	magnesium
HCO_3^-	bicarbonate
CO_3^{--}	carbonate
Cl^-	chloride
SO_4^{--}	sulfate

INTRODUCTION

PURPOSE AND USE LIMITS

The purpose of the system is to rate the suitability of planned coolwater and coldwater reservoirs for selected fish species. It may be applied to reservoirs that meet the following conditions:

1) The reservoir is north of latitude 37° N.

2) Volume weighted total dissolved solids (TDS) of inflow less than 3,000 mg/l.

3) The preponderant ions of inflow are some mixture of K^+, Na^+, Ca^{++}, Mg^{++}, HCO_3^-, CO_3^{--}, Cl^-, and SO_4^{--}, in which HCO_3^- plus CO_3^{--} is no more than 300 mg/l and pH is less than 8.5.

4) The surface area is greater than 3 km^2 (867 acres).

5) The river to be impounded is not grossly polluted. This may be indicated by a diverse fish population and absence of conspicuous fish kills. Quality or use classification by the State in which the river is located may also be a reasonable guide.

6) The proposed reservoir is not to be drawn down to a volume less than 1/4 of maximum capacity.

7) The water body should be an impounded river and not merely a natural lake with a raised level.

The number of species for which a proposed reservoir might be moderately suitable will probably be considerably greater than the number of species actually present in the completed reservoir at any given time. Factors important in determining which fish become important when the reservoir matures include species present in the drainage and those that will become present by stocking by the responsible conservation agency, and temporal population changes due to species interactions and differential harvest.

DATA CHARACTERISTICS

In this section, we present criteria used to select attributes of proposed reservoirs which are most consistent with the purpose and limits of the system. Specific data required and their sources and integration are explained later.

The most restrictive criterion is that attributes be easily acquired some time before reservoir construction begins. In broad terms, this limits attributes to those of the proposed reservoir basin, its operation, characteristics of the inflow, and site climate.

Attributes are limited to those which are readily available in publications, public records, construction agency plans, or are observable during a site visit. Aerial observations may be necessary in some instances, although technical measurements are not required.

SYSTEM LOGIC

Habitat suitability for a reservoir is obtained from a five-digit number (reservoir description) in which the letters A, B, C, D, and E are used to designate each of the five sequential positions of primary attributes. Each primary attribute is derived from one or more "simple" secondary attributes, which are usually single "raw" facts, and each primary attribute has an individual rating of 1, 2, or 3. The composite pattern of these individual primary attribute ratings can be interpreted as having a single expression (rating) of overall habitat suitability (i.e., low, low medium, high medium, or high[2]). System logic is diagrammed in Figure 1.

The primary attributes referred to in positions A-E are:

A - Temperature;

B - Mineral turbidity;

C - Nonliving cover (structure);

D - Maximum drawdown and timing of drawdown;

E - Frequency of shallow coves.

Secondary attributes are listed, beginning on page 21. Each of the 243 possible reservoir descriptions for a species (permutations of three levels of suitability for each of five attributes) is listed in Tables 1-5 in an orderly progression, 11111 to 33333, with corresponding suitability ratings of L (low), LM (low medium), HM (high medium), or H (high).

Rules that were used in deciding the meanings of the five-digit reservoir descriptions, in terms of habitat suitability ratings, are listed in Appendix A for black crappie (Pomoxis nigromaculatus), white sucker (Catostomus commersoni), put-and-grow rainbow trout (Salmo gairdneri), yellow perch (Perca flavescens), and carp (Cyprinus carpio).

As an example, a reservoir description of 31322 would have the following characteristics:

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[2]Four levels of habitat suitability are described: low, low medium, high medium, and high. Habitat Evaluation Procedures (HEP) require that habitat suitability be described in terms of a Habitat Suitability Index (HSI) with values ranging from 0.0 to 1.0. Corresponding numerical values of 0.2, 0.4, 0.7, and 1.0 may be substituted for low, low medium, high medium, and high, in that order.

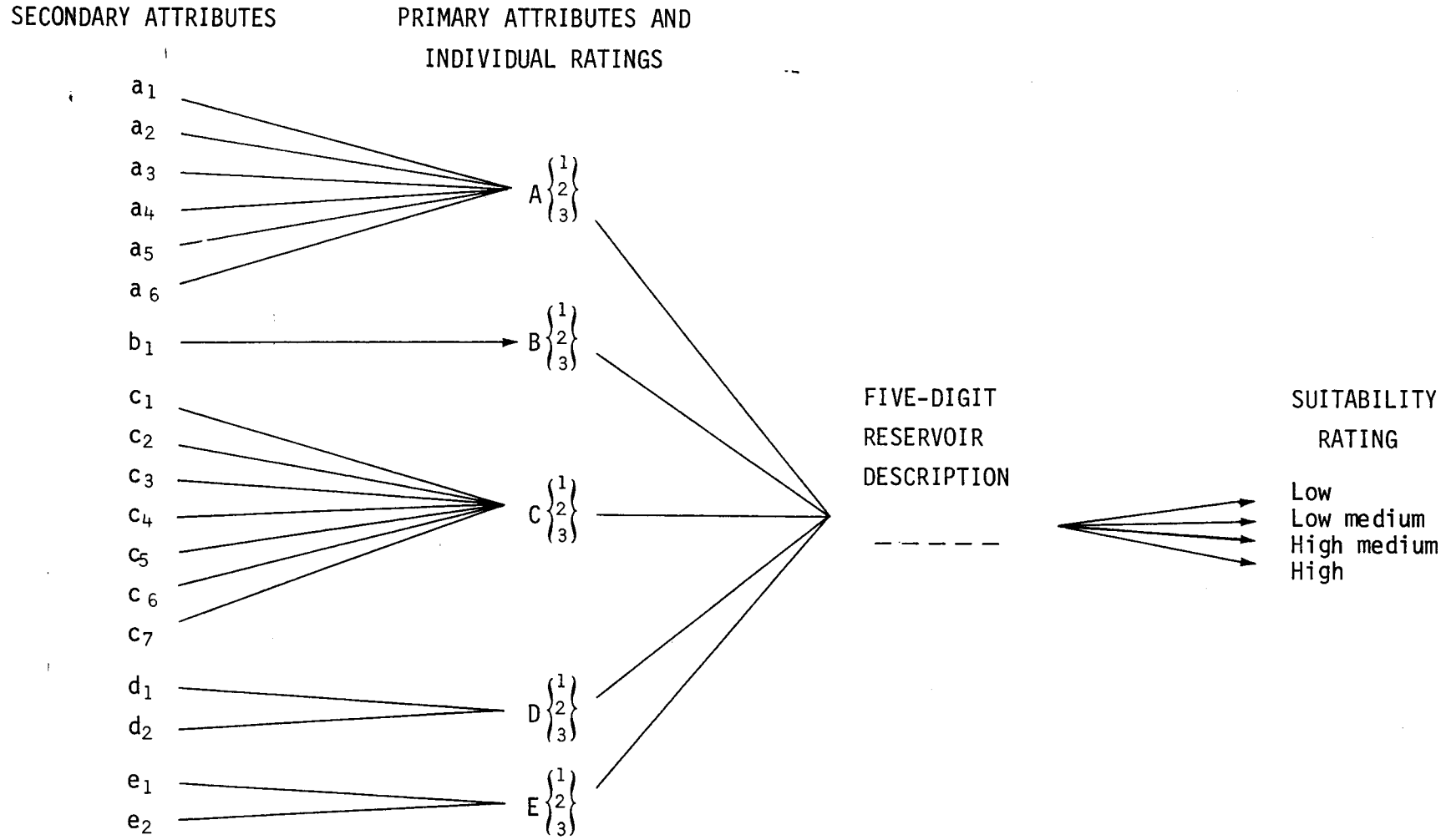


Figure 1. System logic for deriving reservoir habitat suitability ratings from primary and secondary attributes.

Table 1. Reservoir descriptions and suitability ratings for black crappie.

Reservoir description	Suitability	Reservoir description	Suitability	Reservoir description	Suitability
11111	L	12111	L	13111	L
11112	L	12112	L	13112	L
11113	L	12113	L	13113	L
11121	L	12121	L	13121	L
11122	L	12122	L	13122	L
11123	L	12123	L	13123	L
11131	L	12131	L	13131	L
11132	L	12132	L	13132	L
11133	L	12133	LM	13133	LM
11211	L	12211	L	13211	L
11212	L	12212	L	13212	L
11213	L	12213	L	13213	L
11221	L	12221	L	13221	L
11222	L	12222	L	13222	L
11223	L	12223	L	13223	L
11231	L	12231	L	13231	L
11232	L	12232	L	13232	L
11233	L	12233	LM	13233	LM
11311	L	12311	L	13311	L
11312	L	12312	L	13312	L
11313	L	12313	L	13313	L
11321	L	12321	L	13321	L
11322	L	12322	L	13322	L
11323	L	12323	L	13323	L
11331	L	12331	L	13331	L
11332	L	12332	L	13332	L
11333	L	12333	LM	13333	LM

Table 1. (continued)

Reservoir description	Suitability	Reservoir description	Suitability	Reservoir description	Suitability
21111	L	22111	LM	23111	LM
21112	L	22112	LM	23112	LM
21113	L	22113	LM	23113	LM
21121	L	22121	LM	23121	LM
21122	L	22122	HM	23122	HM
21123	L	22123	HM	23123	HM
21131	L	22131	LM	23131	LM
21132	L	22132	HM	23132	HM
21133	L	22133	HM	23133	HM
21211	L	22211	LM	23211	LM
21212	L	22212	LM	23212	LM
21213	L	22213	LM	23213	LM
21221	L	22221	HM	23221	HM
21222	L	22222	HM	23222	HM
21223	L	22223	HM	23223	HM
21231	L	22231	HM	23231	HM
21232	L	22232	HM	23232	HM
21233	L	22233	HM	23233	HM
21311	L	22311	LM	23311	LM
21312	L	22312	LM	23312	LM
21313	L	22313	LM	23313	LM
21321	L	22321	HM	23321	HM
21322	L	22322	HM	23322	HM
21323	L	22323	HM	23323	HM
21331	L	22331	HM	23331	HM
21332	L	22332	HM	23332	HM
21333	L	22333	HM	23333	HM

Table 1. (concluded)

Reservoir description	Suitability	Reservoir description	Suitability	Reservoir description	Suitability
31111	L	32111	LM	33111	LM
31112	L	32112	LM	33112	LM
31113	L	32113	LM	33113	LM
31121	L	32121	LM	33121	LM
31122	L	32122	HM	33122	HM
31123	L	32123	HM	33123	HM
31131	L	32131	LM	33131	LM
31132	L	32132	HM	33132	HM
31133	L	32133	HM	33133	HM
31211	L	32211	LM	33211	LM
31212	L	32212	LM	33212	LM
31213	L	32213	LM	33213	LM
31221	L	32221	HM	33221	HM
31222	L	32222	HM	33222	HM
31223	L	32223	HM	33223	HM
31231	L	32231	HM	33231	HM
31232	L	32232	H	33232	H
31233	L	32233	H	33233	H
31311	L	32311	LM	33311	LM
31312	L	32312	LM	33312	LM
31313	L	32313	LM	33313	LM
31321	L	32321	HM	33321	HM
31322	L	32322	HM	33322	HM
31323	L	32323	HM	33323	HM
31331	L	32331	HM	33331	HM
31332	L	32332	H	33332	H
31333	L	32333	H	33333	H

Table 2. Reservoir descriptions and suitability ratings for white sucker.

Reservoir description	Suitability	Reservoir description	Suitability	Reservoir description	Suitability
11111	L	12111	LM	13111	LM
11112	L	12112	LM	13112	LM
11113	L	12113	LM	13113	LM
11121	L	12121	LM	13121	LM
11122	L	12122	LM	13122	LM
11123	L	12123	LM	13123	LM
11131	L	12131	LM	13131	LM
11132	L	12132	LM	13132	LM
11133	L	12133	LM	13133	LM
11211	L	12211	LM	13211	LM
11212	L	12212	LM	13212	LM
11213	L	12213	LM	13213	LM
11221	L	12221	LM	13221	LM
11222	L	12222	LM	13222	LM
11223	L	12223	LM	13223	LM
11231	L	12231	LM	13231	LM
11232	L	12232	LM	13232	LM
11233	L	12233	LM	13233	LM
11311	L	12311	LM	13311	LM
11312	L	12312	LM	13312	LM
11313	L	12313	LM	13313	LM
11321	L	12321	LM	13321	LM
11322	L	12322	LM	13322	LM
11323	L	12323	LM	13323	LM
11331	L	12331	LM	13331	LM
11332	L	12332	LM	13332	LM
11333	L	12333	LM	13333	LM

Table 2. (continued)

Reservoir description	Suitability	Reservoir description	Suitability	Reservoir description	Suitability
21111	LM	22111	LM	23111	LM
21112	LM	22112	LM	23112	LM
21113	LM	22113	LM	23113	LM
21121	LM	22121	HM	23121	HM
21122	LM	22122	HM	23122	HM
21123	LM	22123	HM	23123	HM
21131	LM	22131	HM	23131	HM
21132	LM	22132	HM	23132	HM
21133	LM	22133	HM	23133	HM
21211	LM	22211	LM	23211	LM
21212	LM	22212	LM	23212	LM
21213	LM	22213	LM	23213	LM
21221	LM	22221	HM	23221	HM
21222	LM	22222	HM	23222	HM
21223	LM	22223	HM	23223	HM
21231	LM	22231	HM	23231	HM
21232	LM	22232	HM	23232	HM
21233	LM	22233	HM	23233	HM
21311	LM	22311	LM	23311	LM
21312	LM	22312	LM	23312	LM
21313	LM	22313	LM	23313	LM
21321	LM	22321	HM	23321	HM
21322	LM	22322	HM	23322	HM
21323	LM	22323	HM	23323	HM
21331	LM	22331	HM	23331	H
21332	LM	22332	HM	23332	H
21333	LM	22333	HM	23333	H

Table 2. (concluded)

Reservoir description	Suitability	Reservoir description	Suitability	Reservoir description	Suitability
31111	LM	32111	LM	33111	LM
31112	LM	32112	LM	33112	LM
31113	LM	32113	LM	33113	LM
31121	LM	32121	HM	33121	H
31122	LM	32122	HM	33122	H
31123	LM	32123	HM	33123	H
31131	LM	32131	HM	33131	H
31132	LM	32132	HM	33132	H
31133	LM	32133	HM	33133	H
31211	LM	32211	LM	33211	LM
31212	LM	32212	LM	33212	LM
31213	LM	32213	LM	33213	LM
31221	LM	32221	HM	33221	HM
31222	LM	32222	HM	33222	HM
31223	LM	32223	HM	33223	HM
31231	LM	32231	H	33231	HM
31232	LM	32232	H	33232	HM
31233	LM	32233	H	33233	HM
31311	LM	32311	LM	33311	LM
31312	LM	32312	LM	33312	LM
31313	LM	32313	LM	33313	LM
31321	LM	32321	HM	33321	HM
31322	LM	32322	HM	33322	HM
31323	LM	32323	HM	33323	HM
31331	LM	32331	H	33331	H
31332	LM	32332	H	33332	H
31333	LM	32333	H	33333	H

Table 3. Reservoir descriptions and suitability ratings for put-and-grow rainbow trout.

Reservoir description	Suitability	Reservoir description	Suitability	Reservoir description	Suitability
11111	L	12111	L	13111	L
11112	L	12112	L	13112	L
11113	L	12113	L	13113	L
11121	L	12121	L	13121	L
11122	L	12122	L	13122	L
11123	L	12123	L	13123	L
11131	L	12131	L	13131	L
11132	L	12132	L	13132	L
11133	L	12133	L	13133	L
11211	L	12211	L	13211	L
11212	L	12212	L	13212	L
11213	L	12213	L	13213	L
11221	L	12221	L	13221	L
11222	L	12222	L	13222	L
11223	L	12223	L	13223	L
11231	L	12231	L	13231	L
11232	L	12232	L	13232	L
11233	L	12233	L	13233	L
11311	L	12311	L	13311	L
11312	L	12312	L	13312	L
11313	L	12313	L	13313	L
11321	L	12321	L	13321	L
11322	L	12322	L	13322	L
11323	L	12323	L	13323	L
11331	L	12331	L	13331	L
11332	L	12332	L	13332	L
11333	L	12333	L	13333	L

Table 3. (continued)

Reservoir description	Suitability	Reservoir description	Suitability	Reservoir description	Suitability
21111	L	22111	LM	23111	LM
21112	L	22112	LM	23112	LM
21113	L	22113	LM	23113	LM
21121	L	22121	LM	23121	LM
21122	L	22122	LM	23122	HM
21123	L	22123	LM	23123	HM
21131	L	22131	LM	23131	LM
21132	L	22132	LM	23132	HM
21133	L	22133	LM	23133	HM
21211	L	22211	LM	23211	LM
21212	L	22212	LM	23212	LM
21213	L	22213	LM	23213	LM
21221	L	22221	LM	23221	LM
21222	L	22222	LM	23222	HM
21223	L	22223	LM	23223	HM
21231	L	22231	LM	23231	LM
21232	L	22232	LM	23232	HM
21233	L	22233	LM	23233	HM
21311	L	22311	LM	23311	LM
21312	L	22312	LM	23312	LM
21313	L	22313	LM	23313	LM
21321	L	22321	LM	23321	LM
21322	L	22322	LM	23322	HM
21323	L	22323	LM	23323	HM
21331	L	22331	LM	23331	LM
21332	L	22332	LM	23332	HM
21333	L	22333	LM	23333	HM

Table 3. (concluded)

Reservoir description	Suitability	Reservoir description	Suitability	Reservoir description	Suitability
31111	L	32111	LM	33111	LM
31112	L	32112	LM	33112	LM
31113	L	32113	LM	33113	LM
31121	L	32121	LM	33121	HM
31122	L	32122	HM	33122	H
31123	L	32123	HM	33123	H
31131	L	32131	LM	33131	HM
31132	L	32132	HM	33132	H
31133	L	32133	HM	33133	H
31211	L	32211	LM	33211	LM
31212	L	32212	LM	33212	LM
31213	L	32213	LM	33213	LM
31221	L	32221	LM	33221	HM
31222	L	32222	HM	33222	H
31223	L	32223	HM	33223	H
31231	L	32231	LM	33231	HM
31232	L	32232	HM	33232	H
31233	L	32233	HM	33233	H
31311	L	32311	LM	33311	LM
31312	L	32312	LM	33312	LM
31313	L	32313	LM	33313	LM
31321	L	32321	LM	33321	HM
31322	L	32322	HM	33322	H
31323	L	32323	HM	33323	H
31331	L	32331	LM	33331	HM
31332	L	32332	HM	33332	H
31333	L	32333	HM	33333	H

Table 4. Reservoir descriptions and suitability ratings for yellow perch.

Reservoir description	Suitability	Reservoir description	Suitability	Reservoir description	Suitability
11111	L	12111	LM	13111	LM
11112	L	12112	LM	13112	LM
11113	L	12113	LM	13113	LM
11121	L	12121	LM	13121	LM
11122	L	12122	LM	13122	LM
11123	L	12123	LM	13123	LM
11131	L	12131	LM	13131	LM
11132	L	12132	LM	13132	LM
11133	L	12133	LM	13133	LM
11211	L	12211	LM	13211	LM
11212	L	12212	LM	13212	LM
11213	L	12213	LM	13213	LM
11221	L	12221	LM	13221	LM
11222	L	12222	LM	13222	LM
11223	L	12223	LM	13223	LM
11231	L	12231	LM	13231	LM
11232	L	12232	LM	13232	LM
11233	L	12233	LM	13233	LM
11311	L	12311	LM	13311	LM
11312	L	12312	LM	13312	LM
11313	L	12313	LM	13313	LM
11321	L	12321	LM	13321	LM
11322	L	12322	LM	13322	LM
11323	L	12323	LM	13323	LM
11331	L	12331	LM	13331	LM
11332	L	12332	LM	13332	LM
11333	L	12333	LM	13333	LM

Table 4. (continued)

Reservoir description	Suitability	Reservoir description	Suitability	Reservoir description	Suitability
21111	L	22111	LM	23111	LM
21112	L	22112	LM	23112	LM
21113	L	22113	LM	23113	LM
21121	L	22121	LM	23121	HM
21122	L	22122	LM	23122	HM
21123	L	22123	LM	23123	HM
21131	L	22131	LM	23131	HM
21132	L	22132	LM	23132	HM
21133	L	22133	LM	23133	HM
21211	L	22211	LM	23211	LM
21212	L	22212	LM	23212	LM
21213	L	22213	LM	23213	LM
21221	L	22221	LM	23221	HM
21222	L	22222	LM	23222	HM
21223	L	22223	LM	23223	HM
21231	L	22231	LM	23231	HM
21232	L	22232	LM	23232	H
21233	L	22233	LM	23233	H
21311	L	22311	LM	23311	LM
21312	L	22312	LM	23312	LM
21313	L	22313	LM	23313	LM
21321	L	22321	LM	23321	HM
21322	L	22322	LM	23322	HM
21323	L	22323	LM	23323	HM
21331	L	22331	LM	23331	HM
21332	L	22332	LM	23332	H
21333	L	22333	LM	23333	H

Table 4. (concluded)

Reservoir description	Suitability	Reservoir description	Suitability	Reservoir description	Suitability
31111	L	32111	LM	33111	LM
31112	L	32112	LM	33112	LM
31113	L	32113	LM	33113	LM
31121	L	32121	LM	33121	HM
31122	L	32122	LM	33122	HM
31123	L	32123	LM	33123	HM
31131	L	32131	LM	33131	HM
31132	L	32132	LM	33132	HM
31133	L	32133	LM	33133	HM
31211	L	32211	LM	33211	LM
31212	L	32212	LM	33212	LM
31213	L	32213	LM	33213	LM
31221	L	32221	LM	33221	HM
31222	L	32222	LM	33222	H
31223	L	32223	LM	33223	H
31231	L	32231	LM	33231	HM
31232	L	32232	LM	33232	H
31233	L	32233	LM	33233	H
31311	L	32311	LM	33311	LM
31312	L	32312	LM	33312	LM
31313	L	32313	LM	33313	LM
31321	L	32321	LM	33321	HM
31322	L	32322	LM	33322	H
31323	L	32323	LM	33323	H
31331	L	32331	LM	33331	HM
31332	L	32332	LM	33332	H
31333	L	32333	LM	33333	H

Table 5. Reservoir descriptions and suitability ratings for carp.

Reservoir description	Suitability	Reservoir description	Suitability	Reservoir description	Suitability
11111	L	12111	L	13111	L
11112	L	12112	L	13112	L
11113	L	12113	L	13113	L
11121	L	12121	L	13121	L
11122	L	12122	L	13122	L
11123	L	12123	L	13123	L
11131	L	12131	L	13131	L
11132	L	12132	L	13132	L
11133	LM	12133	LM	13133	LM
11211	L	12211	L	13211	L
11212	L	12212	L	13212	L
11213	L	12213	L	13213	L
11221	L	12221	L	13221	L
11222	L	12222	L	13222	L
11223	L	12223	L	13223	L
11231	L	12231	L	13231	L
11232	L	12232	L	13232	L
11233	LM	12233	LM	13233	LM
11311	L	12311	L	13311	L
11312	L	12312	L	13312	L
11313	L	12313	L	13313	L
11321	L	12321	L	13321	L
11322	L	12322	L	13322	L
11323	L	12323	L	13323	L
11331	L	12331	L	13331	L
11332	L	12332	L	13332	L
11333	LM	12333	LM	13333	LM

Table 5. (continued)

Reservoir description	Suitability	Reservoir description	Suitability	Reservoir description	Suitability
21111	L	22111	LM	23111	LM
21112	L	22112	LM	23112	LM
21113	L	22113	LM	23113	LM
21121	LM	22121	HM	23121	HM
21122	LM	22122	HM	23122	H
21123	LM	22123	HM	23123	H
21131	LM	22131	HM	23131	HM
21132	LM	22132	H	23132	H
21133	LM	22133	H	23133	H
21211	L	22211	LM	23211	LM
21212	L	22212	LM	23212	LM
21213	L	22213	LM	23213	LM
21221	LM	22221	HM	23221	HM
21222	LM	22222	HM	23222	H
21223	LM	22223	HM	23223	H
21231	LM	22231	HM	23231	HM
21232	LM	22232	H	23232	H
21233	LM	22233	H	23233	H
21311	L	22311	LM	23311	LM
21312	L	22312	LM	23312	LM
21313	L	22313	LM	23313	LM
21321	LM	22321	HM	23321	HM
21322	LM	22322	HM	23322	H
21323	LM	22323	HM	23323	H
21331	LM	22331	HM	23331	HM
21332	LM	22332	H	23332	H
21333	LM	22333	H	23333	H

Table 5. (concluded)

Reservoir description	Suitability	Reservoir description	Suitability	Reservoir description	Suitability
31111	L	32111	LM	33111	LM
31112	L	32112	LM	33112	LM
31113	L	32113	LM	33113	LM
31121	LM	32121	HM	33121	HM
31122	LM	32122	HM	33122	H
31123	LM	32123	HM	33123	H
31131	LM	32131	HM	33131	HM
31132	LM	32132	H	33132	H
31133	LM	32133	H	33133	H
31211	L	32211	LM	33211	LM
31212	L	32212	LM	33212	LM
31213	L	32213	LM	33213	LM
31221	LM	32221	HM	33221	HM
31222	LM	32222	HM	33222	H
31223	LM	32223	HM	33223	H
31231	LM	32231	HM	33231	HM
31232	LM	32232	H	33232	H
31233	LM	32233	H	33233	H
31311	L	32311	LM	33311	LM
31312	L	32312	LM	33312	LM
31313	L	32313	LM	33313	LM
31321	LM	32321	HM	33321	HM
31322	LM	32322	HM	33322	H
31323	LM	32323	HM	33323	H
31331	LM	32331	HM	33331	HM
31332	LM	32332	H	33332	H
31333	LM	32333	H	33333	H

A. Temperature (3) (Option I: warmwater species). More than 170 days in the growing season; mean July air temperature greater than 70° F.

B. Mineral turbidity (1). Predicted Secchi disk depth less than 0.5 m.

C. Nonliving cover (3). Boulders, standing timber, and talus cover 30-70% of deepest half of lake bottom; over 30% of bottom is covered by structure units over 7 cm in diameter and 0.5 m high; mean height of these units is greater than 20% of greatest mean depth and density exceeds 100 units/ha.

D. Drawdown (2). Extent of maximum drawdown over 5 years is 2 to 5 m, and it occurs during August through October.

E. Shallow cove frequency (2). Mean depth is 10 to 20 m and shoreline development factor is between 5 and 10.

The meaning of 31322 as an expression of habitat suitability is based on the composite pattern of attribute ratings rather than a score derived from mathematical manipulation of the numbers.

The importance of an attribute in assigning an overall suitability varies with the fish species being considered. Importance is based on statements in the literature validated, when possible, by the status of populations of the species in existing reservoirs which exhibit an extreme of the attribute. For example, high turbidity might exclude one species but not another depending on the sensitivity of the species being considered. If a species were excluded by turbidity, the status of the other attributes would have no weight in assigning overall suitability. In contrast, a species tolerant of high turbidity might not become as numerous or grow as rapidly if turbidity were extremely high but it would not be excluded; therefore, one or more of the other attributes would have weight in judging overall suitability.

To give another example, a warmwater species might be excluded by a description of 13322 but 13333 would indicate the presence of stable, shallow coves in the spring and could possibly mitigate the low surface temperature sufficiently to allow the species to survive and reproduce to a limited extent.

The foregoing irregular attribute relations and others can be expressed more easily with pattern systems than with scoring systems. If experience or further review indicates ratings assigned to a species are inappropriate, two approaches can be used to change the rating system. The simplest approach is to change the suitability rating. However, the rationale leading to a change of one rating will probably require changes in other ratings. For complete consistency, the rules for deriving the ratings from primary attribute scores (Appendix A) should be changed so that the new rating may be derived from the rules. An alternative to changing the rules is to change the method of deriving primary attribute scores from secondary attributes. However, in some cases this alternative may also require changes in the rules.

INSTRUCTION OVERVIEW

1. Read all instructions first.

2. Examine attribute matrices to determine which secondary attributes need to be estimated for the species under consideration.

3. Check suggested sources or other material to obtain values for secondary attributes.

4. Determine primary attribute scores using appropriate attribute matrices.

5. Compile five-digit reservoir description from the five primary attribute scores.

6. From Tables 1-5, find the appropriate five-digit reservoir description and read corresponding habitat suitability.

SECONDARY ATTRIBUTE LISTING WITH SOURCES

Levels of all or most of the secondary attributes listed below will need to be determined to use this model. In some situations, fewer measurements may be made. This can be determined as you progress through the work sheet and will depend on the species used and individual reservoir descriptions. See attribute matrices beginning on page 27 for units in which attributes are measured.

GROWING SEASON

Growing season is the mean number of days between the last spring and the first fall frost at the reservoir site. This information is recorded at weather stations which may not be at the reservoir site; however, an estimate of the growing season can usually be made by using data from the nearest weather station if care is taken to obtain data from stations at similar altitudes and latitudes.

Sources: National Oceanic and Atmospheric Administration. 1974. Climates of the States. Vol. I, Eastern States plus Puerto Rico and U.S. Virgin Islands; Vol. II, Western States including Alaska and Hawaii. Water Information Center, Inc., Port Washington, N.Y. 975 pp.

National Oceanic and Atmospheric Administration. 1978. Climates of the States, with current tables of normals 1941-1970 and means and extremes to 1975. James A. Ruffner, compiler. Vol. I, Alabama-Montana; Vol. II, Nebraska-Wyoming, Puerto Rico, and U.S. Virgin Islands. Gale Research Company, Detroit, Mich.

U.S. Weather Bureau. 1959-1960. Climates of the States, 1951-1960. Climatography of the United States, Series 86. U.S. Dept. Commerce, Washington, D.C.

MEAN JULY AIR TEMPERATURE

If mean July air temperatures at the reservoir site are not available, follow same procedures for growing season determination.

Sources: The three sources listed under Growing Season and the following:

U.S. Weather Bureau. Climatic summary of the United States, Bulletin W supplement, 1931-1952. Climatography of the United States, Series 11. U.S. Dept. Commerce, Washington, D.C.

STORAGE RATIO

Storage ratio is the ratio of reservoir volume (at the listed elevation) to the average annual discharge.

Sources: Construction agency records.

Operations schedule.

USGS flow records plus reservoir volume.

DEPTH OF OUTLET IN RELATION TO MEAN DEPTH

The outlet depth is the midline depth of the principal outlet at the listed surface area. The position of the outlet in relation to mean depth is above, below, or within the middle one-third of the mean depth (± 0.33 mean depth).

Sources: Construction agency records.

Mean depth = volume/surface area (at full basin).

MAXIMUM FETCH

The maximum uninterrupted distance across the lake or reservoir's surface is the maximum fetch.

Sources: Contour map.

MEAN DEPTH

Mean depth is the lake volume divided by its surface area.

Sources: Reservoir specifications from construction agency.

MINERAL TURBIDITY

Turbidity of inflow streams is not a reliable indicator of turbidity levels to be expected in the impounded reservoir; therefore, an approximation of expected turbidity can be obtained from direct or estimated Secchi disk readings at nearby reservoirs with similar morphometry, inflow streams, altitude, operational regime, and other associated factors.

AREAL EXTENT OF BOTTOM COVERED BY STRUCTURAL UNITS

Designated structural units are rubble, boulders, tree stumps, or similar structures which are over 7 cm in diameter and 50 cm high.

Sources: Site visit.

PERCENT STRUCTURAL UNITS ON DEEPEST HALF OF BOTTOM

The deepest half of bottom is that portion of lake or reservoir lying below the mid-depth contour.

Sources: Contour map.

Site visit.

MEAN HEIGHT OF STRUCTURAL UNITS AS A PERCENT OF MEAN DEPTH

Designated mean depth is at full basin; structural units are boulders, standing timber, talus fields, or any combination of these or similar structures.

Sources: Contour map.

Site visit.

Environmental impact statement.

MEAN DENSITY OF STRUCTURAL UNITS

Density is expressed here as number of structural units per hectare.

Sources: Site visit.

LINEAR EXTENT OF STRUCTURE IN DEEPEST HALF OF RESERVOIR

Structures here refer to cliffs or shoals >45°. To determine:

1) use a planimeter to obtain the total length of the mid-depth contour,

2) identify all sections of contour intervals adjacent to or below the mid-depth contour which have slopes >45°,[3]

3) sum the lengths of sections obtained in (2) and divide by the length obtained in (1). Multiplied by 100; the answer is a percentage.

Sources: Site visit.

Contour map.

LINEAR EXTENT OF STRUCTURE AT FULL BASIN

Structures are cliffs or shoals >45° and determination is similar to that of the preceding attribute, except that full basin contour (greatest shoreline length) replaces the mid-depth contour.

Sources: Site visit.

Contour map.

MEAN HEIGHT OF CLIFFS OR SHOALS AS A PERCENT OF MEAN DEPTH

Cliffs or shoals are designated below high water line and mean depth is at full basin.

Sources: Contour map.

Site visit.

[3]A helpful tool for this step is the USGS Topo Map - Land Area and Slope Indicator for use on 7.5 and 15 minute series maps available from Reproduction Specialites, Inc., 4990 East Asbury Avenue, Denver, CO 80222.

EXTENT OF MAXIMUM DRAWDOWN

Extent of drawdown is expressed in meters (m), and the period of consideration is five years.

Sources: Construction agency operating plans.

TIME OF MAXIMUM DRAWDOWN

Time is month(s) of the year; it is assumed the reservoir is static or filling in other months.

Sources: Construction agency operating plans.

Environmental impact statement.

SHORELINE DEVELOPMENT FACTOR (D_L)

The shoreline development factor is an index of shoreline complexity and is calculated from the equation

$$D_L = \frac{L}{2\sqrt{\pi A}}$$

where L = shoreline length in m and A = surface area (m^2). If an exact area estimate is not available, a rough estimate of D_L can be obtained by comparing the shape of the proposed reservoir to the reservoirs with known shoreline development factors given in Appendix B.

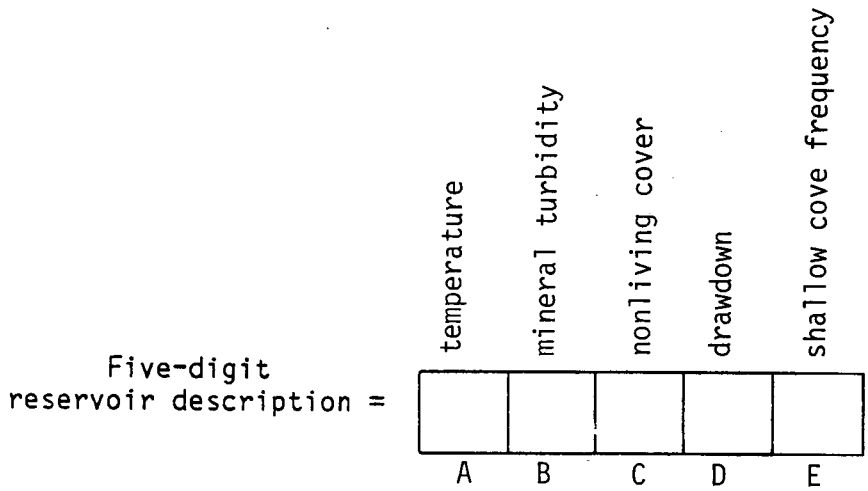
Sources: Contour map.

Appendix B.

THE USE OF PRIMARY ATTRIBUTE SCORES TO DETERMINE RESERVOIR DESCRIPTIONS AND SPECIES SUITABILITY

Water temperature, mineral turbidity, nonliving cover, extent and timing of drawdown, and frequency of shallow coves constitute the five primary attributes. These attributes are composites of two or more secondary attributes with the exception of mineral turbidity, which is based on levels of a single attribute. Primary attribute scores are derived by examining the relationship between selected secondary attribute scores in a two-dimensional matrix. To determine a primary attribute score, locate the number (usually 1, 2, or 3) in the matrix that corresponds to the levels of the secondary attributes being considered on the matrix axes. In calculating the primary attribute score for nonliving cover, two or more matrices may need to be examined sequentially before deriving the score. Numerical values entered in the octagons become the primary attribute scores if all appropriate conditions have been met.

The five-digit number resulting from scoring each of the five primary attributes becomes the reservoir description.



To determine the suitability of the reservoir for the species of concern, find the reservoir description and its corresponding suitability in Tables 1 through 5.

MATRICES FOR DERIVING PRIMARY ATTRIBUTE SCORES

TEMPERATURE

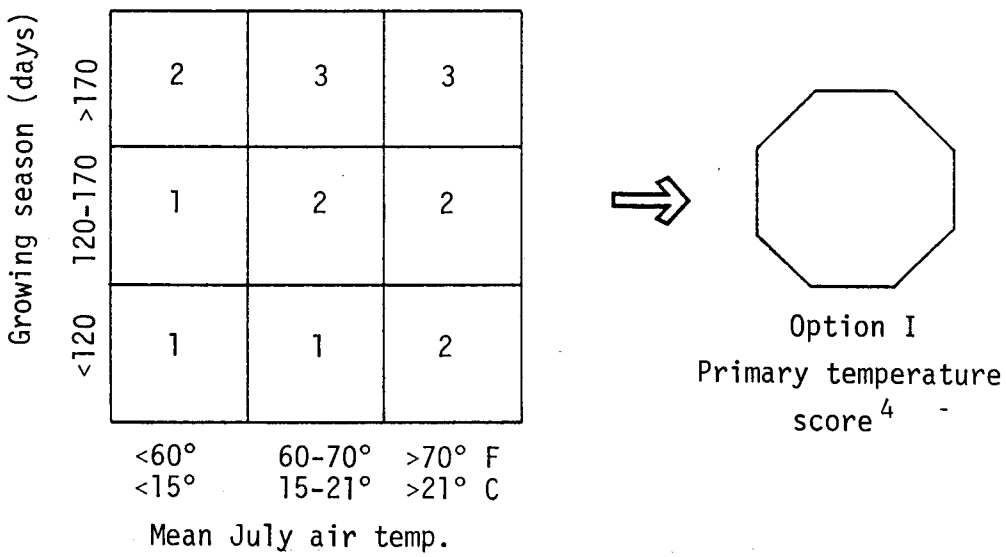
A separate temperature score option is required for each species-temperature group; i.e., warmwater, coolwater and coldwater species. Examples of species in each of these groups are given below.

Warmwater	Coolwater	Coldwater
Black crappie	White sucker	Rainbow trout
Smallmouth bass	Walleye	
Carp	Yellow perch	

The species-temperature group of concern must be identified before proceeding with development of the numerical reservoir description.

Option I: Warmwater Species

a. Climate score

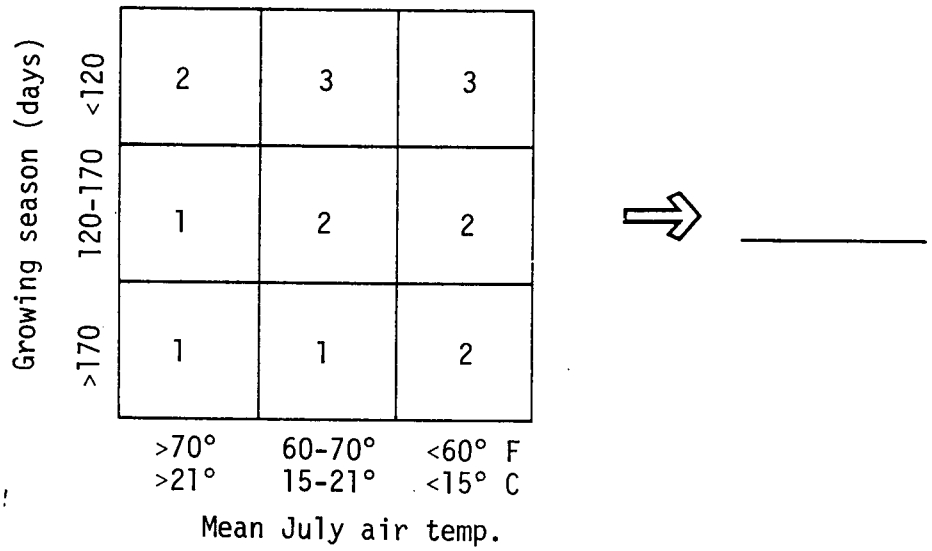


[4]When you encounter an octagon, STOP. The number you place here is the primary attribute score for this attribute. Only one score will be calculated for each of the five primary attributes. When one is completed, go on to next primary attribute.

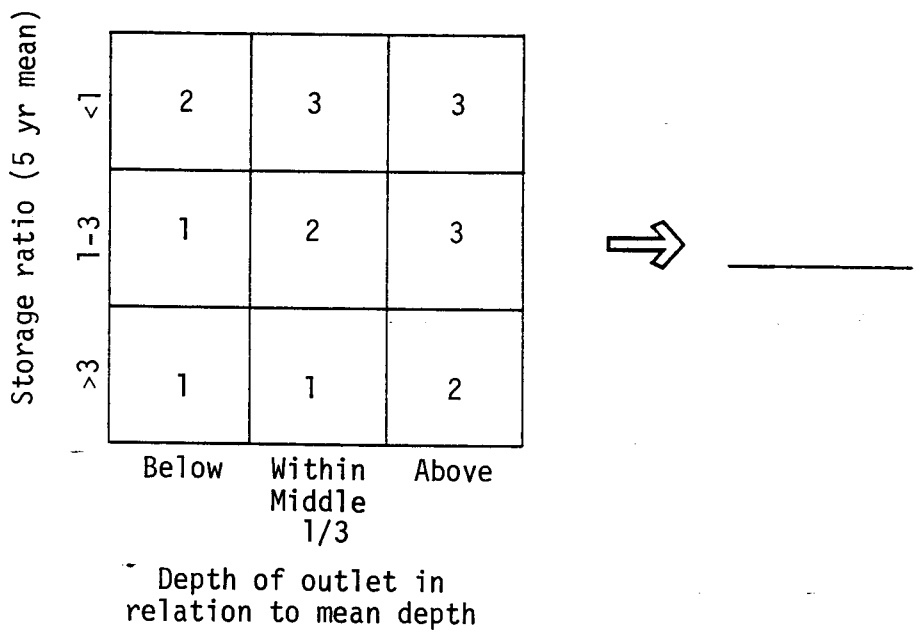
Option II: Coolwater Species

To obtain a temperature score for coolwater fishes, three secondary attributes need to be determined: 1) climate score; 2) operations score; and 3) stratification score. After they are determined, scores for these secondary attributes are combined to arrive at the primary temperature score.

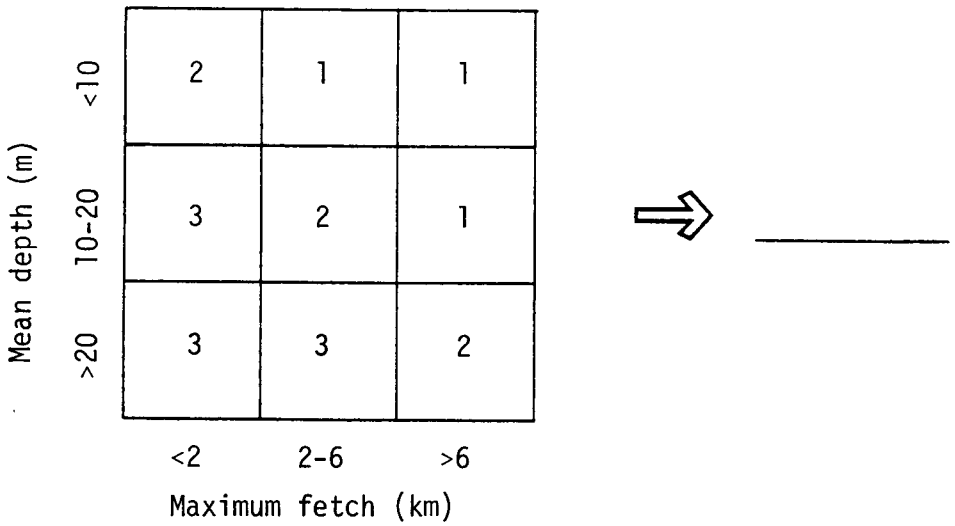
a. Climate score



b. Operations score

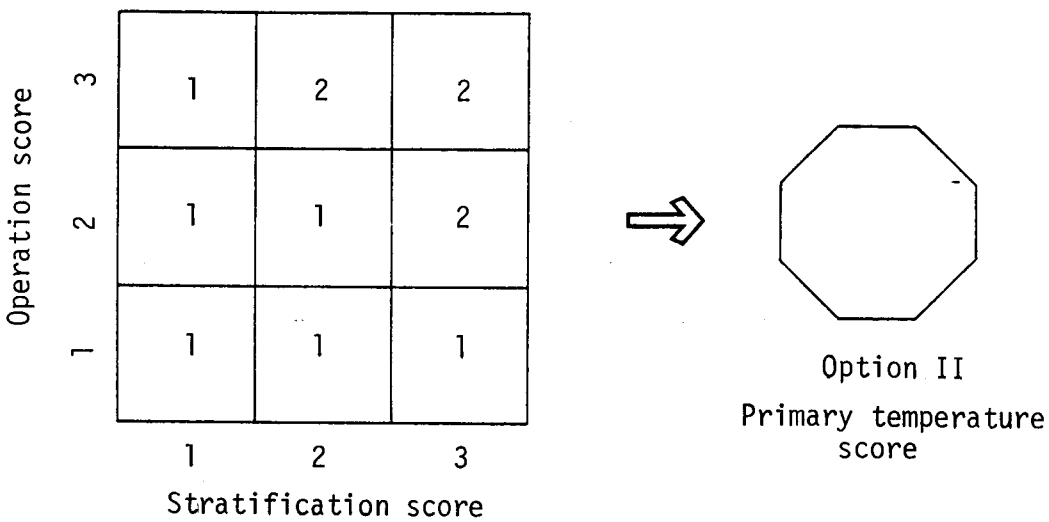


c. Stratification score

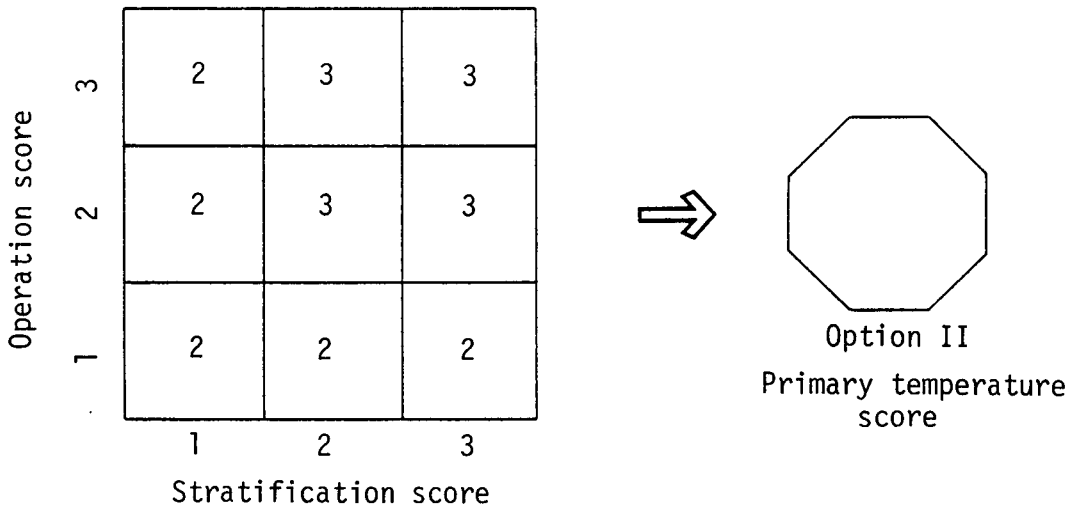


The climate score (a) above is used to determine which of the following three matrices will be used to derive the Option II coolwater species temperature score.

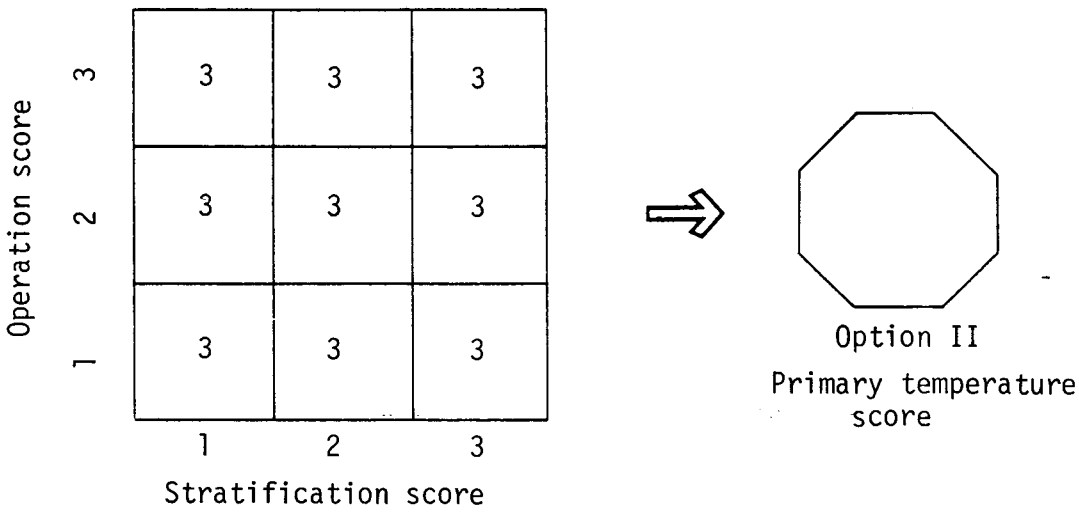
If climate score = 1



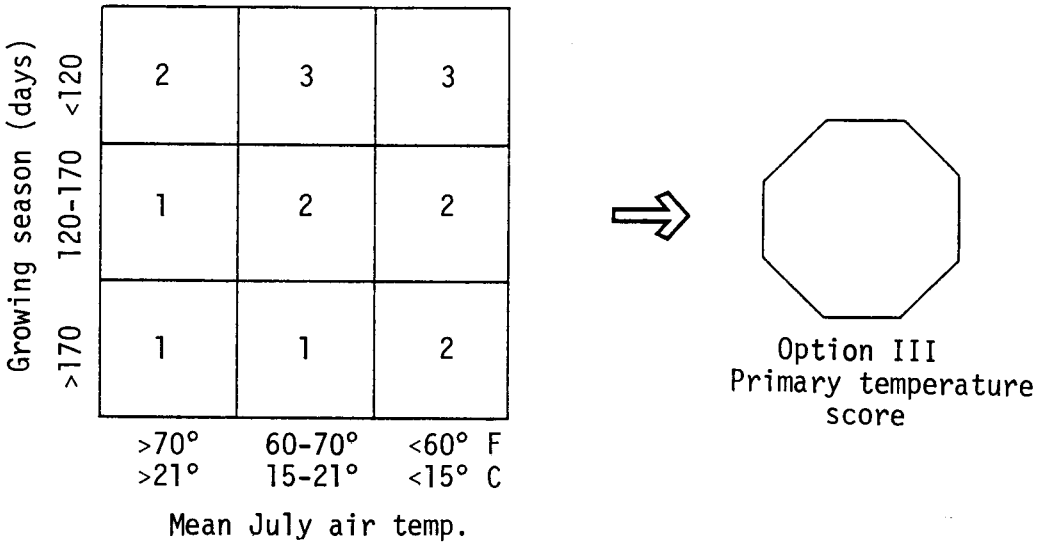
If climate score = 2



If climate score = 3



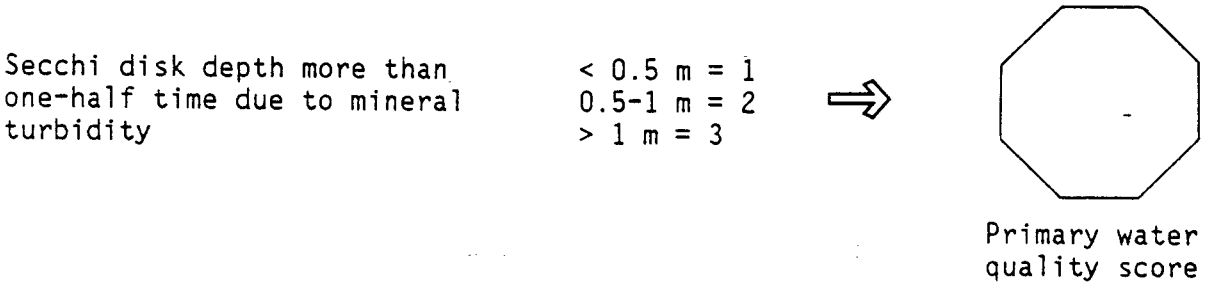
Option III: Coldwater Species [5]



MINERAL TURBIDITY

The degree of muddiness of the water, caused by mineral turbidity, is estimated from either direct or approximate Secchi disk readings at nearby similar reservoirs. Approximate Secchi disk depths can be based on user judgement if direct measurements are not possible.

Three levels of mineral turbidity are considered:



[5] This matrix differs from that used for warmwater species in that July air temperatures and growing season are reversed on their axes. The scoring procedure remains the same.

NONLIVING COVER

Rating of nonliving cover or structure is based on the types of cover that are likely to be inundated by the new reservoir. Three cover options are described:

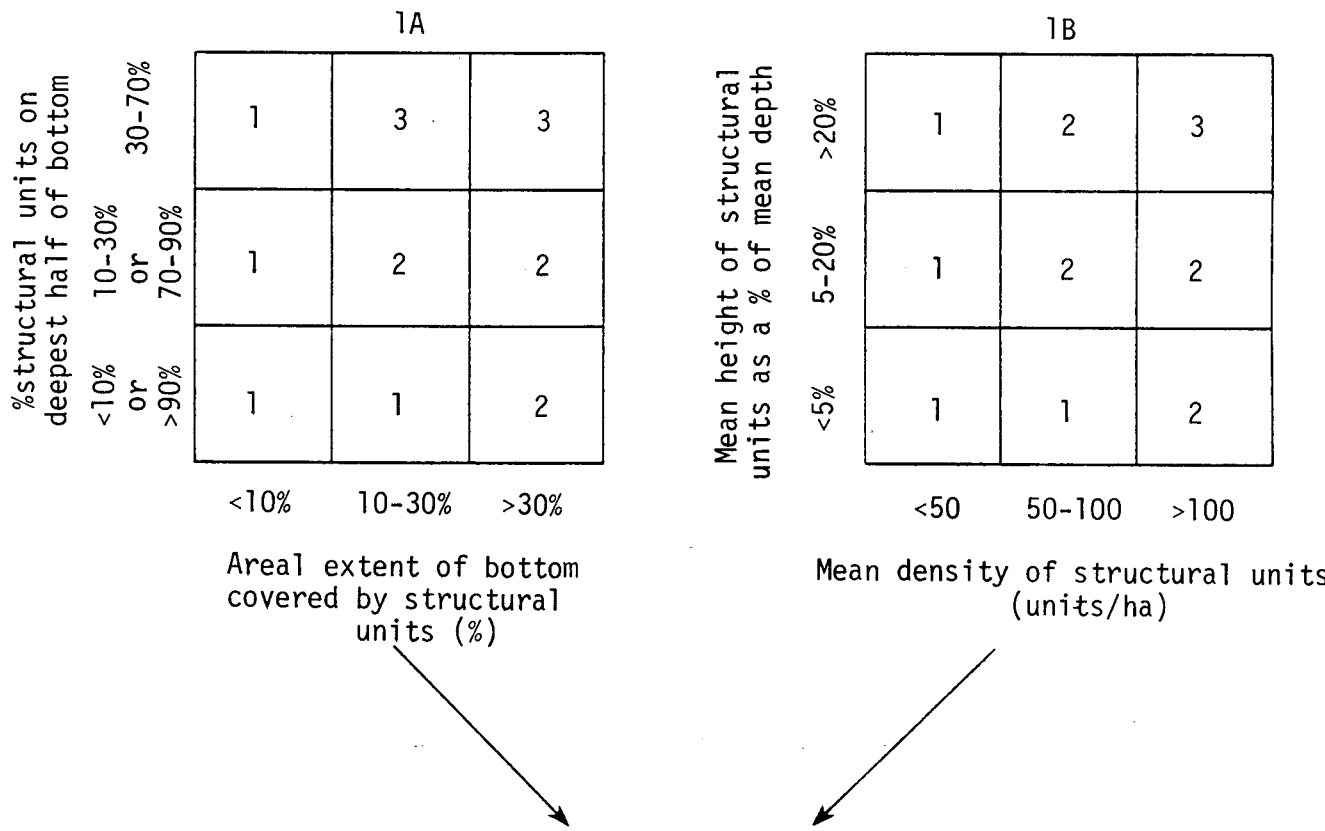
I. Boulders, standing timber, talus fields - individually or in any combination.

II. Steep (> 45°) shoals or cliffs.

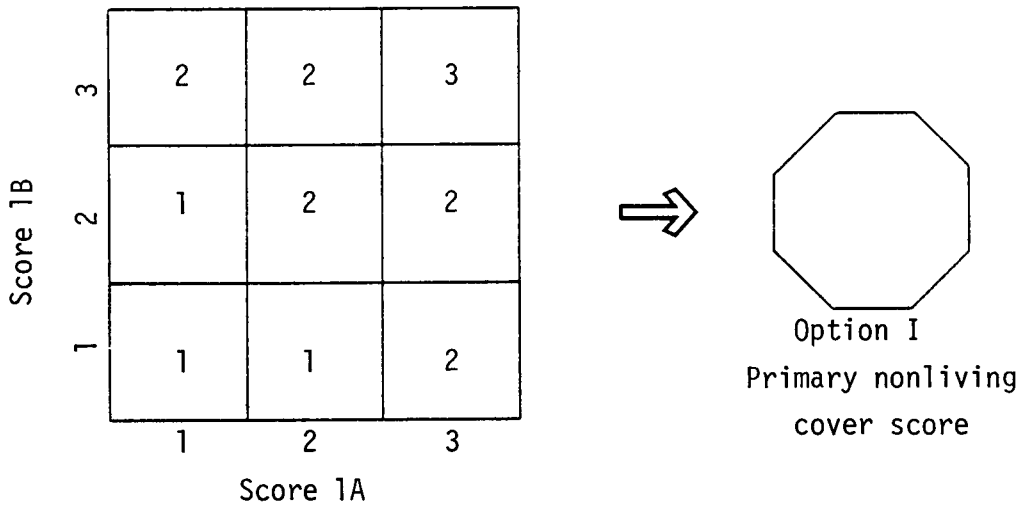
III. Combination of options I and II.

Nonliving Cover Matrix 1

Option I. Boulder, standing timber, and talus

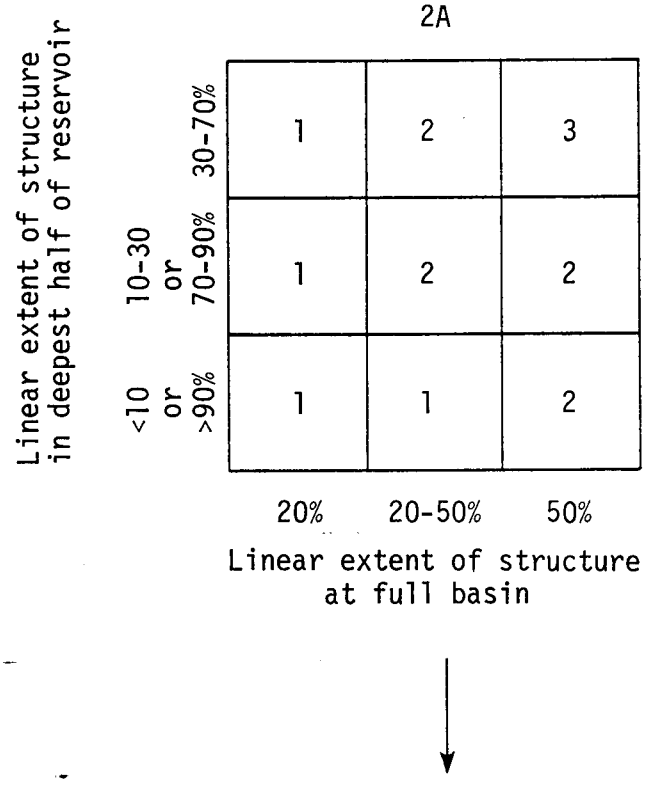


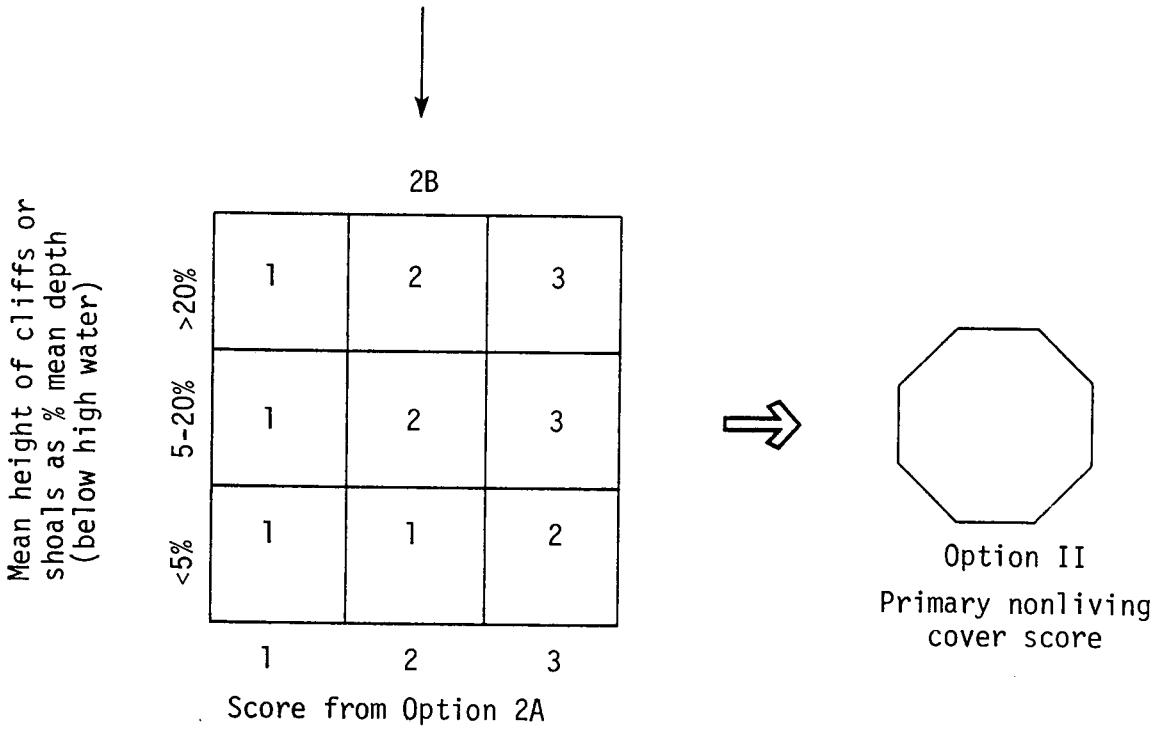
Cover rating for Option I is derived from a combination of scores from Matrix 1A and 1B.



Nonliving Cover Matrix 2

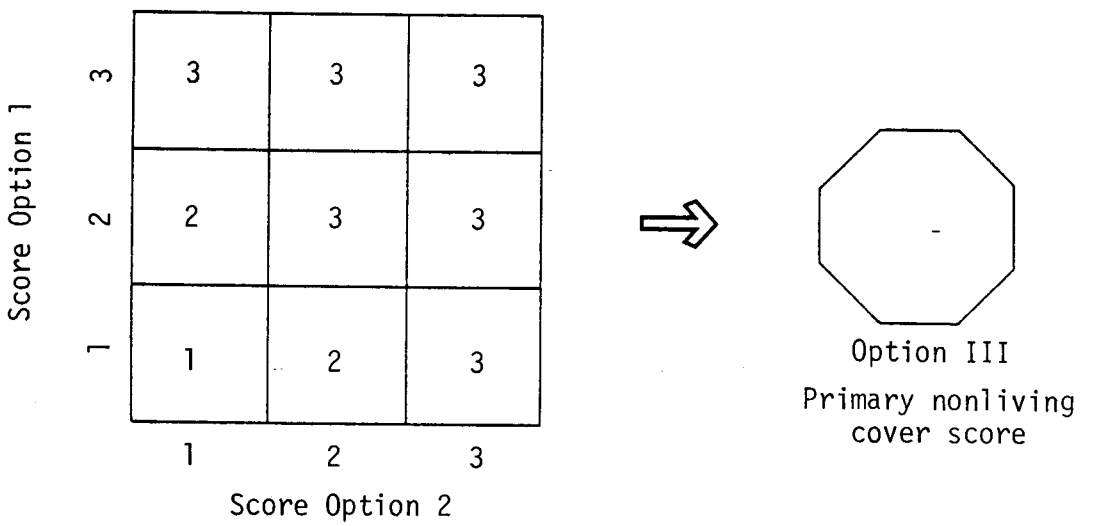
Option II. Cliffs and shoals





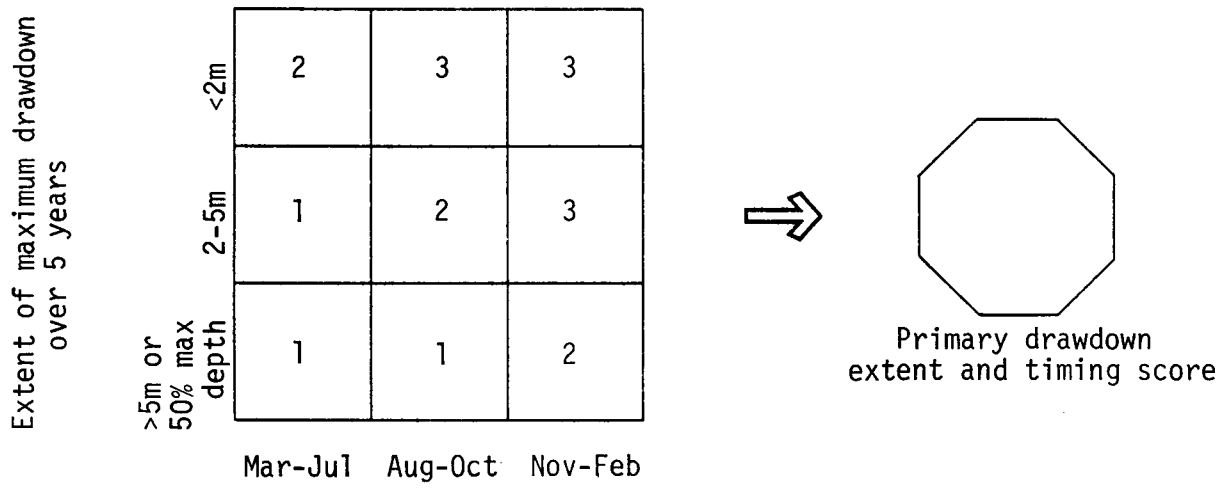
Nonliving Cover Matrix 3

Option III. If talus fields are present in association with cliffs or shoals, the scores from Options I and II are combined to derive the final structure score:

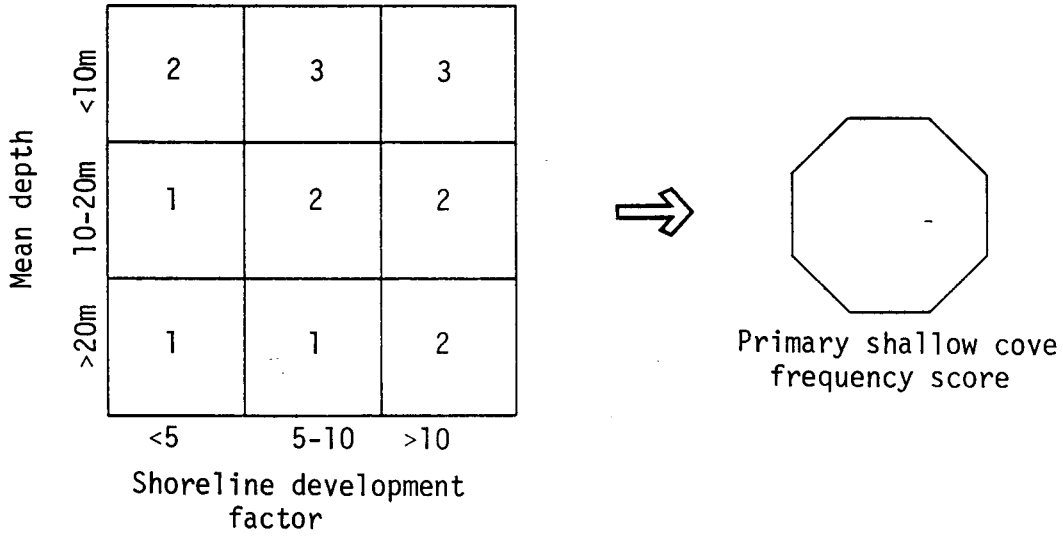


DRAWDOWN EXTENT AND TIMING

Fluctuation score



SHALLOW COVE FREQUENCY



BIBLIOGRAPHY

The following information sources are provided to aid the user in calculating secondary attribute scores. These only represent a partial list of available sources, and the user may wish to consult other documents. Annotated entries represent suggested sources for the user to examine. The remaining sources plus annotated entries were used by the authors to determine species-habitat interactions and reservoir habitat suitability ratings.

Benci, J. F., and T. B. McKee. 1977. Colorado monthly temperature and precipitation summary for period 1951-1970. Colorado Climatology Office, Dept. Atmospheric Science, Colorado State Univ., Ft. Collins.
A monthly climatological summary for 162 National Weather Service reporting stations in Colorado. Only stations with 20 years of data (temperature, precipitation, or both) from 1951-1970 were selected. A State map showing station locations is presented with a table of stations, county, latitude, longitude, elevation, and observation time. This is followed by detailed monthly summaries (including maximum, minimum, and mean temperatures) for each alphabetically listed station. This is an excellent example of a statewide, long-term weather summary, and similar types of publications may be put out by other States.

Cross, F. B. 1967. Handbook of fishes of Kansas. Museum of Natural History Miscellaneous Publication No. 45. Univ. of Kansas, Lawrence. 357 pp.

Duerre, D. C. 1973. Ecological investigations of lakes, streams and impoundments in North Dakota (surveys). Dingell-Johnson Division, Project F-2-R-20, Study II, Jobs IIa and IIB, Report A-1028, North Dakota State Game and Fish Department.

Hall, G. E. (Ed.). 1971. Reservoir fisheries and limnology. American Fisheries Society, Special Publication No. 8, Washington, D.C. 511 pp.

Hokanson, K. E. F. 1977. Temperature requirements of some percids and adaptations to the seasonal temperature cycle. J. Fish. Res. Board Can. 34:1524-1550.

Jenkins, R. M., and D. I. Morais. 1971. Reservoir sport fishing effort and harvest in relation to environmental variables. Pages 371-384 in G. E. Hall (Ed.), Reservoir fisheries and limnology. American Fisheries Society Special Publication No. 8, Washington, D.C. 511 pp.
The influence of selected environmental variables (area, mean depth, outlet depth, thermocline depth, water level fluctuation, storage ratio, shore development, total dissolved solids, growing season, and age of impoundment) on sport fishing effort and harvest were analyzed for 103 U.S. reservoirs (> 200 ha). Data for these reservoirs are presented in a table insert along with data on harvest of rainbow trout, catfishes, sunfishes, and black basses.

Koster, W. J. 1957. Guide to the fishes of New Mexico. University of New Mexico Press in cooperation with New Mexico Department of Game and Fish. Albuquerque, N. Mex. 116 pp.

LaRivers, I. 1962. Fishes and fisheries of Nevada. Nevada State Fish and Game Commission. Carson City, Nevada. 782 pp.

Leidy, G. R., and R. M. Jenkins. 1977. The development of fishery compartments and population rate coefficients for use in reservoir ecosystem modeling. USDI Fish and Wildlife Service, National Reservoir Research Program. Fayetteville, Arkansas. Final Contract Report 4-77-1. Prepared for Office, Chief of Engineers, U.S. Army, Washington, D.C. (Vicksburg, U.S. Army Engineer Waterways Experiment Station.)

Appendixes contain physical and chemical descriptions of 187 Corps of Engineers reservoirs > 500 acres in surface area, sport and commercial fish harvests, estimated standing crops of fish species groups from summer cove rotenone sampling, and temperature tolerance and preference data for various reservoir fish species. Not much data on western reservoirs.

National Oceanic and Atmospheric Administration. 1974. Climates of the States. Vol. I, Eastern States; Vol. II, Western States including Alaska and Hawaii. Water Information Center, Inc., Port Washington, N.Y. 975 pp.

National Oceanic and Atmospheric Administration. 1978. Climates of the States, with current tables of normals 1941-1970 and means and extremes to 1975. James A. Ruffner, compiler. Vol. 1, Alabama-Montana; Vol. 2, Nebraska-Wyoming, Puerto Rico, and U.S. Virgin Islands. Gale Research Company, Detroit, Mich.
Based on Climatography of the United States, No. 60, issued serially 1959-1960 by U.S. Weather Bureau, and data from NOAA. For each alphabetically listed State, there is a narrative with references and bibliography; tables of freeze data for numerous stations (from which growing season is obtained); and tables of normals (temperature and precipitation) by climatological division or drainage area, for the period 1931-1960.

Nelson, W. R., and C. H. Walburg. 1977. Population dynamics of yellow perch (Perca flavescens), sauger (Stizostedion canadense), and walleye (S. vitreum vitreum) in four main stem Missouri River reservoirs. J. Fish. Res. Board Can. 34:1748-1763.

Pflieger, W. L. 1975. The fishes of Missouri. Missouri Department of Conservation. 343 pp.

Puttmann, S., and L. Finnell. 1979. Warmwater fisheries investigations. Federal Aid Project F-34-R-11, Job Progress Report. Colorado Division of Wildlife. 47 pp.

Scott, W. B., and E. J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada, Bulletin 184. Ottawa. 966 pp.

Smith-Vaniz, W. F. 1968. Freshwater fishes of Alabama. Auburn Univ. Agricultural Experiment Station. Auburn, AL. 211 pp.

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U.S. Environmental Protection Agency. 1975. A compendium of lake and reservoir data collected by the National Eutrophication Survey in the Northeast and North-central U.S. Working paper number 474. National Eutroph. Surv. Environmental Monitoring Support Lab. Las Vegas, NV.
Contains mainly water quality data, including mean Secchi disk extinction depths. (not seen)

U.S. Geological Survey. Water resources data. Part 2, Water Quality Records. (Annual reports for various States.) U.S. Dept. Interior. From the 1964 water year (Oct 1-Sep 30) to the present, these reports are issued on a State-by-State basis. From 1941-1963, water quality records were compiled from 14 major drainage basins within the United States and were called "Quality of Surface Waters of the United States." Data are listed in a downstream sequence beginning at the headwaters, and each natural drainage is called a Part and is numbered 1-14. Records range from "spot" observations to tables of continuous daily records.

U.S. Weather Bureau. Climatic summary of the United States, Bulletin W (1930 edition). Climatography of the United States. Series 10. U.S. Dept. Commerce, Washington, D.C.

U.S. Weather Bureau. Climatic summary of the United States; Supplement for 1931-1952 (Bulletin W supplement). Climatography of the United States. Series 11. U.S. Dept. of Commerce, Washington, D.C. First supplement to 1930 edition. (not seen)

U.S. Weather Bureau. Climatic summary of the United States, Bulletin W, Second supplement, 1951-1960. Climatography of the United States. Series 86. U.S. Dept. of Commerce, Washington, D.C.
A five-volume State-by-State compilation of temperature and precipitation data for each weather station in the State. Monthly mean temperatures are listed by year for the period (1951-1960) and are compared with the normals for that station. Especially useful is the section on station history, which includes the county where the station is located, latitude, longitude, elevation, distance and direction to nearest post office, and the month and year records began (and ended) within the time period.

APPENDIX A

RULES FOR ASSIGNING RESERVOIR HABITAT SUITABILITY RATINGS

The following sets of rules form the bases for determining the level of habitat suitability for all 243 five-digit reservoir descriptions for each species under consideration. To use the rules, proceed sequentially only; all low, all low medium, all high medium, and all high. When one or more conditions for a rule are met, use the corresponding suitability rating. Experience or further review may dictate changes in one or more rating assignments. In each description, A = temperature; B = mineral turbidity; C = nonliving cover; D = maximum drawdown; and E = frequency of shallow, protected coves.

BLACK CRAPPIE[6]

If A = 1 (unless D = E = 3) or B = 1	Low
If not as above, and C = E = 1 or D = 1	Low Medium
If not as above, and A = 2 or D = 2 or C = 1 or E = 1	High Medium
If not as above	High

[6]A = Temperature Option I, warmwater species.

WHITE SUCKER[7,8]

If A = B = 1	Low
If not as above, and A = 1 or B = 1 or D = 1	Low Medium
If not as above, and A = B = 2 or A = D = 2 or B = D = 2	High Medium
If not as above	High

PUT-AND-GROW RAINBOW TROUT[9,10]

If A = 1 or B = 1	Low
If not as above, and A = B = 2 or D = 1 or E = 1 and A ≠ 2 or E = 1 and B ≠ 2	Low Medium
If not as above, and A = 2 or B = 2 or E = 1	High Medium
If not as above	High

YELLOW PERCH[8]

If B = 1	Low
If not as above, and A = 1 or D = 1 or B = 2	Low Medium
If not as above, and C = 1 or E = 1 or A = D = 2	High Medium
If not as above	High

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[7]C and E were irrelevant for white sucker and were not used.
[8]A = Temperature Option II, coolwater species.
[9]C is irrelevant for rainbow trout and was not used.
[10]A = Temperature Option III, coldwater species.

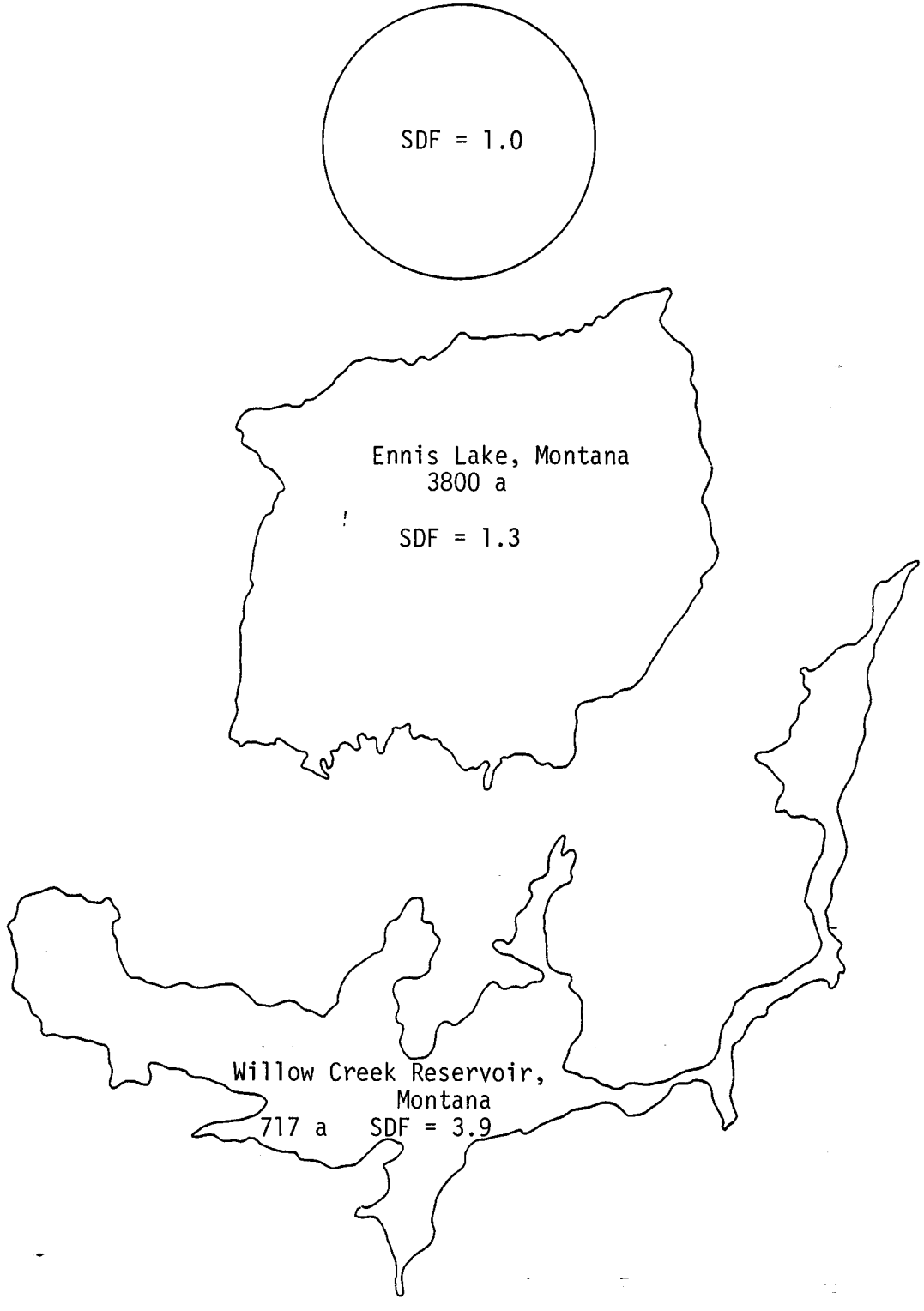
CARP[11,12]

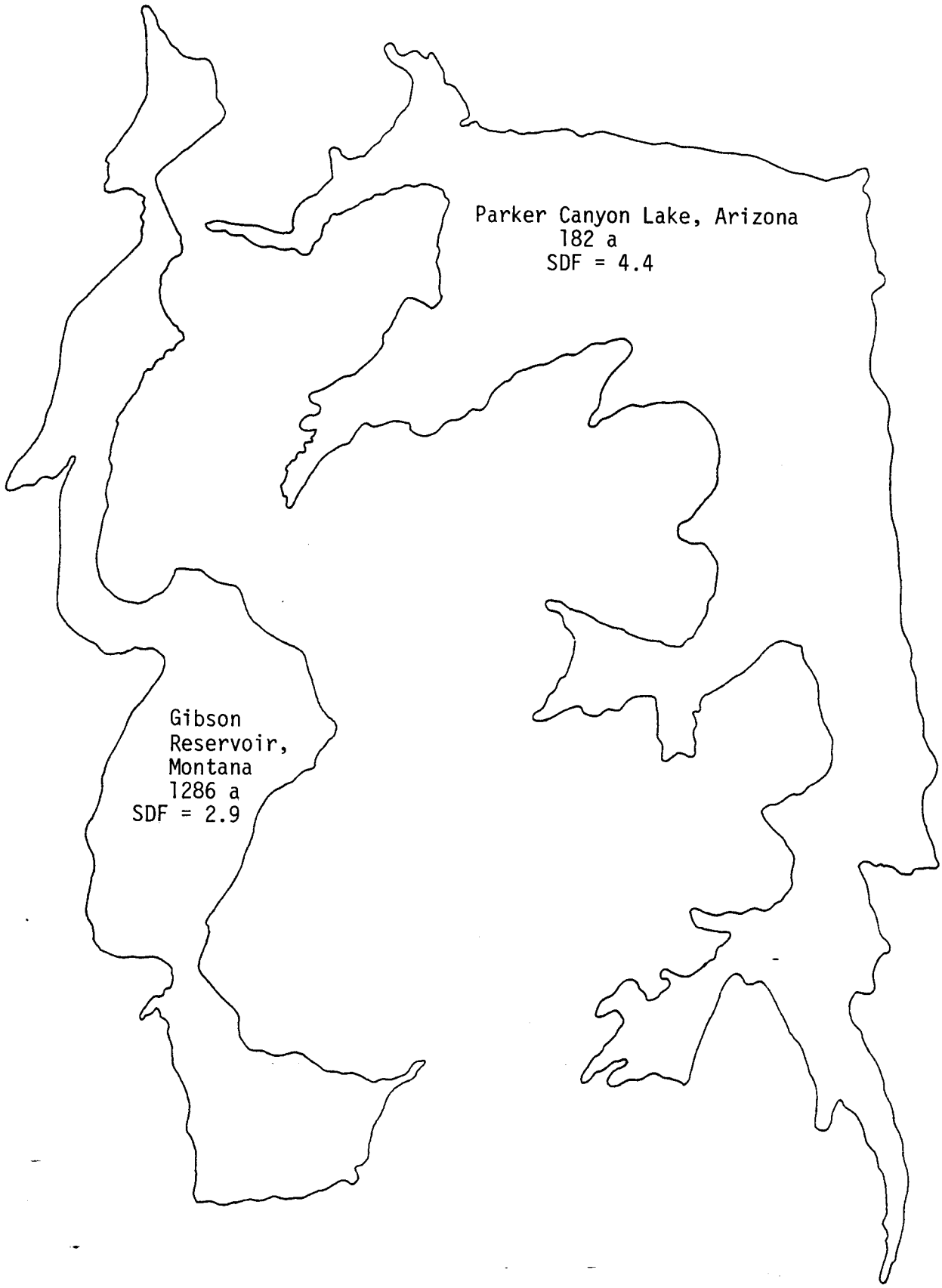
If A = 1 and D = 1 or A = 1 and E = 1 or A = 1 and E = 2 or B = D = 1	Low
If not as above, and A = 1 or B = 1 or D = 1	Low Medium
If not as above, and E = 1 or B = D = 2 or	High Medium
If not as above	High

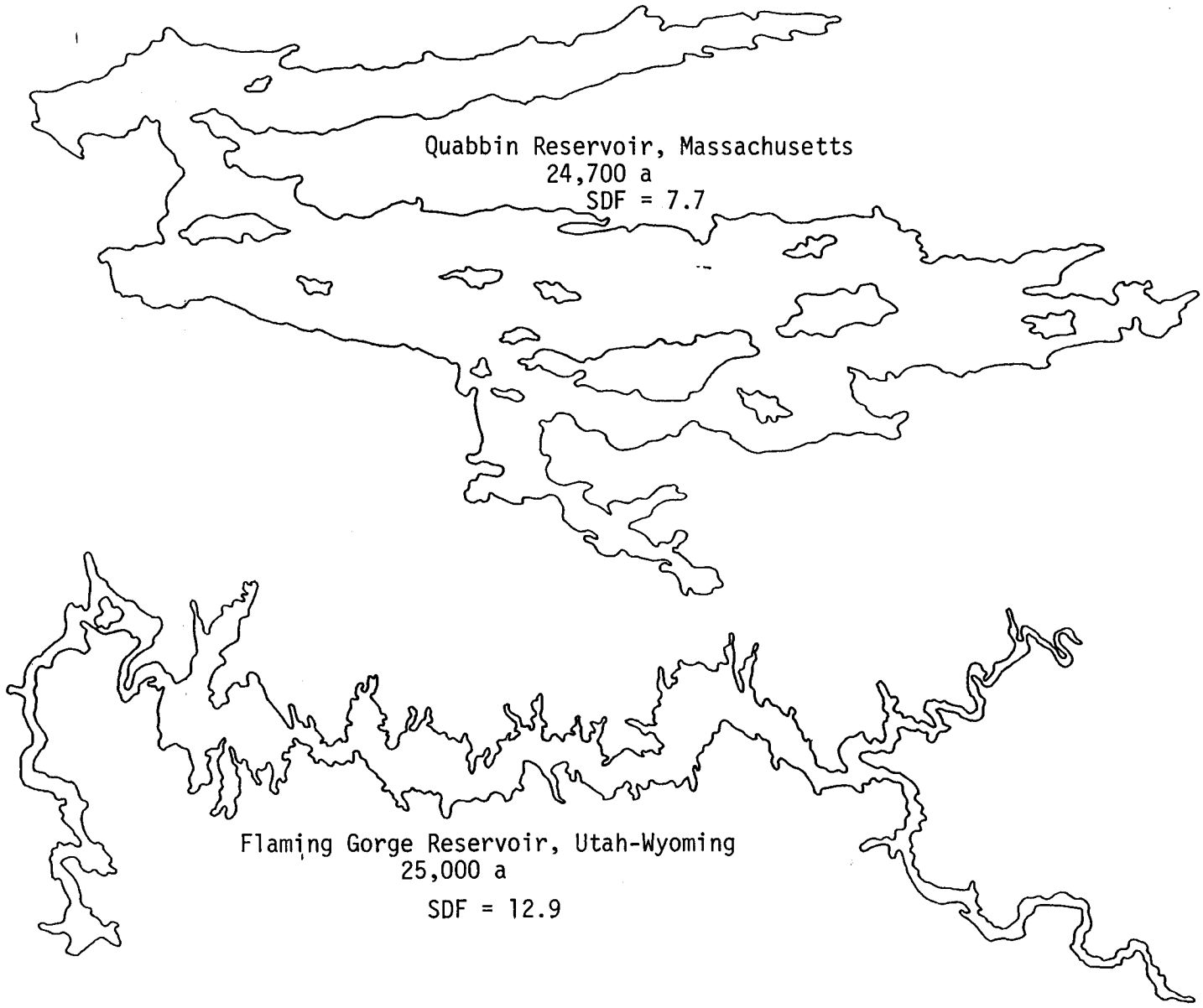
[11] C is irrelevant for carp and was not used.
[12] A = Temperature Option I, warmwater species.

APPENDIX B

LAKESHORES AND KNOWN SHORELINE DEVELOPMENT FACTORS

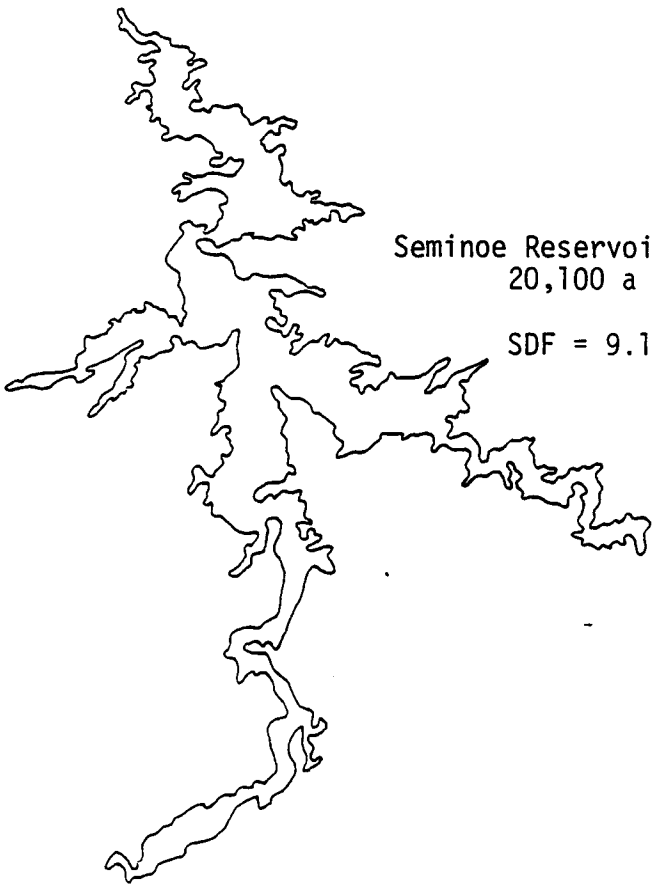



Parker Canyon Lake, Arizona
182 a
SDF = 4.4
Gibson
Reservoir,
Montana
1286 a
SDF = 2.9


Quabbin Reservoir, Massachusetts
24,700 a
SDF = 7.7
Flaming Gorge Reservoir, Utah-Wyoming
25,000 a
SDF = 12.9

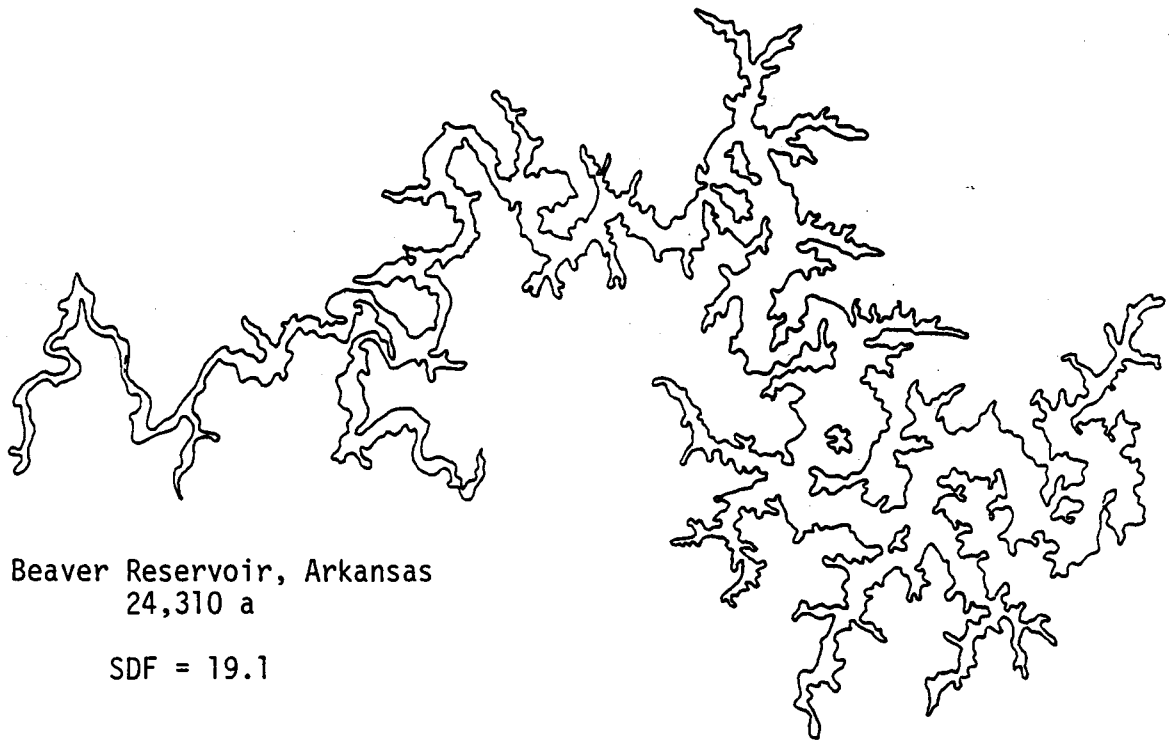
Pathfinder Reservoir, Wyoming
22,000 a

SDF = 10.6



Seminoe Reservoir, Wyoming
20,100 a

SDF = 9.1



Beaver Reservoir, Arkansas
24,310 a

SDF = 19.1

50272-101

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5. Report Date
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16. Abstract (Limit: 200 words)

A technique is described for measuring reservoir habitat suitability based on a composite score for five primary reservoir attributes (temperature, turbidity, nonliving cover, drawdown, and shallow cove frequency). The value of each primary attribute is determined from secondary attributes, which are easily obtained from published data and on-site inspection of the proposed reservoir basin. Subsequently, the use of primary attribute scores to determine reservoir habitat suitability for five selected fish species is described. This approach has the advantages of procedural simplicity and ready availability of input data. The intended use is during the early planning stages of reservoir construction projects, when the outcomes of alternative plans are being evaluated.

This is one in a series of publications describing the applications of Habitat Suitability Indices (HSI's), a corollary to the U.S. Fish and Wildlife Service's Habitat Evaluation Procedures.

17. Document Analysis a. Descriptors

Reservoirs
Habitability
Fishes

b. Identifiers/Open-Ended Terms

Habitat
Habitat Suitability Index

c. COSATI Field/Group

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